CEMENT
AND
CEMENT MANUFACTURE

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Testing of Cement.

THE subject of cement testing has been prominent during the last few years; several of the standard cement specifications of the world have been revised, and in this country there have been public discussions on papers read on the subject. There are two reasons for the present feeling of dissatisfaction with cement testing as practised to-day, first, the methods of testing for strength adopted in different countries give widely different results on the same cement, and, second, the results of cement tests are not a reliable guide to the strength of concrete made with the cement. In a paper submitted by Haegermann to the International Congress for Testing Materials at Amsterdam in 1927 it was shown that with various national methods of testing the proportion of water used for making 3 : 1 mortar tests ranged from 7 per cent. to 10.5 per cent.; with this variation it is not surprising that the maximum test result obtained was 70 per cent. higher than the minimum. The result of a United States test of cement, in which the percentage of water used for 3 : 1 mortar usually exceeds 10 per cent., is no guide to those accustomed to British methods of testing, in which the percentage of water used is generally below 8 per cent.

All would agree that an international cement specification is desirable, but the obstacles to be overcome in getting international agreement on this subject include not only the difference in the percentage of water, but differences in the size of the standard sand used, in the methods of filling the moulds, and in the size and shape of moulds. Another formidable obstacle to international agreement is the objections which some nations would certainly raise if they were called upon to adopt means of making any particular test which gave lower results than those hitherto employed. To the uninitiated the effect of changing the method of testing would not be appreciated and the conclusion would be reached that the quality of the cement had depreciated. This last obstacle, however, could be overcome if an entirely new test were adopted, and this solution of the problem might provide the opportunity for devising a test which could be accepted as a reliable indication of the strength-forming quality of cement when used as concrete.

In a paper by Glanville and Reid recently read before the Institution of Structural Engineers, evidence is presented that there is a direct relation between the compression strengths of a 3 : 1 sand/cement mortar gauged with 12½ per cent. of water and 1 : 2 : 4 concrete with a water-cement ratio of 0.6. The proposal to use 12½ per cent. of water for sand/cement mortar is so divergent from the existing methods of British cement testing as to make it unpopular, and at the same time there is a feeling that if a compression test is to be adopted it might as well be of a concrete giving direct results instead of with a substitute which, if in the form of a wet mortar, would inevitably give low results which would compare unfavourably with those of other countries using a lower percentage of water. The recently published Code of Practice sets a standard for compression tests of concrete, and, although the London County Council suggest that material alterations be made to those proposals before they are incorporated in the L.C.C. Regulations for Reinforced Concrete, there is a possibility that this method of testing may become the basis of tests adopted unofficially at first, but ultimately leading to universal adoption and substitution for the present tensile tests.

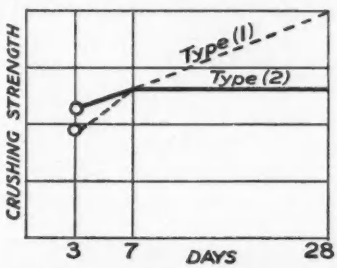
The subject of heat development during the setting and hardening of cement has also been much discussed of late, notably in connection with large masses of concrete in various dams in the United States. In this case the heat development is considered objectionable because of the high temperatures reached in the centres of large masses of concrete, from which heat escapes very slowly. The cooling from the temperatures of 100 deg. F. or higher that may be reached in such conditions is considered to cause sufficient contraction to be responsible for the cracking that has been observed in some cases. It is well to remember, however, that the heat development of cement during setting and hardening, while disadvantageous in the circumstances just described, is of considerable value in many other circumstances in which cement is used. The rise in temperature of concrete accelerates the hardening, and this is a distinct benefit. It is perhaps not fully recognised that the higher and more rapid rise of temperature which is the characteristic of rapid-hardening cements is one of the causes of the rapidity of hardening.

Returning to the subject of cement testing, and the desire that the tests should give a direct indication of the strength of concrete in which the cement is used, it must be appreciated that the laboratory test-piece is always of small dimensions and the heat developed by the cement during setting is quickly dissipated by radiation ; thus the test piece never gains the acceleration of strength obtained by larger masses of concrete where the setting heat is not dissipated for some considerable time. For this reason, no laboratory test can be a strictly reliable guide of the strength of concrete in use.

In an article by Marcotte in *Chemie et Industrie* [1934 (31) 6], the suggestion is made that the rise in temperature and the calculated heat development of a cement may give sufficient information to show the rate of setting and rate of strength development of the cement. There is much in favour of this suggestion. Those accustomed to examining the records of temperature rise observed in labora-

tory tests are able to distinguish at once between normal Portland cements and rapid-hardening cements, and with closer observation it may be possible to arrive at fairly accurate ideas of strength up to seven days. To the chemist it will be obvious that there must be a direct relation between heat development and strength because the latter is the result of chemical action and the rate and degree of chemical action are shown by the temperature attained and the heat evolved. Much investigation and accumulation of data would be required before this point of view could be accepted as generally applicable, and a different formula connecting heat development and strength might be needed for Portland cements with high silica and high alumina contents respectively. But in the search for a cement test with an entirely new basis a temperature test is worth consideration.

Use of the Rankin Diagram in Cement Burning. S. SOLACOGLU. *Zement*, Vol. 22, pp. 17, 33, 1933.—A series of synthetic cements is burnt in an electric furnace or, where necessary, in the oxy-acetylene flame. The resulting cements are ground and tested by Kühl's miniature testing process* and the results are compared by means of the "relative strength values."* The mixtures for burning were arranged so that the silica modulus varied in nine steps from 2.0 to 0.0. The ratio $Fe_2O_3/(SiO_2+Al_2O_3)$ was maintained constant throughout, viz., 5/25. For each silica modulus a number of burns were made with mixes of varying lime content between lime saturation factor (L.S.F.) 100 and 20. The Rankin diagram was used to plot the mixtures investigated. The results for the nine silica moduli are plotted as curves of L.S.F. against relative strength value. Most interesting are the curves obtained for aluminous cement,



in which there are two distinct strength maxima as the L.S.F. decreases. This indicates the existence of two types of aluminous cement, viz., type (1) (the ordinary fused cement) with higher lime content, and type (2) (not hitherto described) with lower lime content. Type (1) has high initial strength, but the subsequent increase in strength is small. Type (2) also has high initial strength, but somewhat lower than type (1); in this case, however, there is an important increase in strength with time. The crushing strength history of the two types is shown in the figure. Type (1) has a minimum melting point (1,335 deg. C.), that of type (2) (1,415 deg.) being higher. The following are percentage analyses of the two types:—Type (1): SiO_2 4.89, Al_2O_3 43.68, Fe_2O_3 9.78, CaO 41.65. Silica mod. 0.09, alumina mod. 4.5, L.S.F. 45. Type (2): SiO_2 5.65, Al_2O_3 50.80, Fe_2O_3 11.29, CaO 32.26. Silica mod. 0.09, alumina mod. 4.5, L.S.F. 30.

* See "Cement Chemistry in Theory and Practice," by Hans Kühl. Published by Concrete Publications, Ltd. Price 7s. 6d.

Long-Distance Pneumatic Cement Transport.

ONE of the largest engineering works now in progress is the construction of Boulder Dam, also known as Hoover Dam, in the canyon of the Colorado river between the States of Arizona and Nevada, U.S.A. The dam will be 727 ft. high, 650 ft. thick at the foot, and 45 ft. thick at the top. About 4 million cubic yards of concrete are to be used, requiring about 4½ million barrels of cement.

The cement is transported in bulk in railway trucks from four cement works in California and one in Utah to the unloading station shown in the lower right-hand corner of the map (Fig. 1). Each truck holds 300 barrels, so that about 15,000 trucks of cement will be required. The cement is discharged into the eight circular silos indicated on the map as "cement blending silos." The cements from the different works are stored in different silos, from which they can be discharged in predetermined proportions by means of a system of extracting worms and submitted to primary blending.

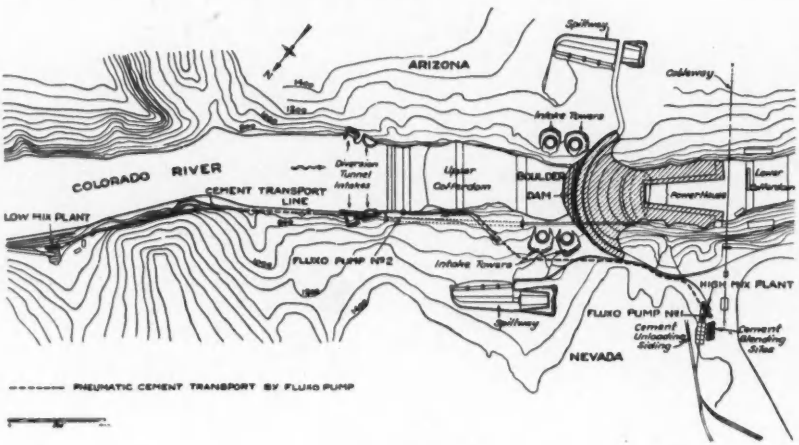


Fig. 1.

By means of Fluxo pumps the cement is conveyed pneumatically from the blending silos to two concrete mixing plants, called the "Lomix" and "Himix" plants, the first of which (Fig. 2) is situated at the bottom of the canyon, while the second is 500 ft. higher. The "Himix" plant is situated about 100 ft. from the cement blending silos, whereas the "Lomix" plant (shown to the left of the map) is more than a mile distant from the silos. The journey by railway from the blending silos to the "Lomix" plant is more than 14 miles long, and is on an inclination of 3.4 in 100, whereas the length of the pipeline for the pneumatic transport is only one mile. Pneumatic transport of cement offers another decided advantage as compared with railway transport, in that the

turbulent action of the mixture of air and cement in the pipeline considerably intensifies the blending of the different cements.

The selection of a reliable and economical cement pump to handle 2½ million barrels of cement from the blending silos to the " Lomix " plant and 2 million barrels to the " Himix " plant was therefore an important problem, in view of the necessity of keeping pace with the concreting programme and the early date for completing the concreting. No type of pump had hitherto pumped the required capacity of 450 barrels per hour over a distance approaching 5,600 ft. The greatest distance over which the Fluxo pump had hitherto been called upon to convey cement was 1,500 ft. This distance, however, by no means indicated the limit of its performance ; in fact the characteristics of this pump showed no theoretical difficulties in pumping the cement the full 5,600 ft.

Fig. 2.

Nevertheless, considering the great importance of supplying the cement to schedule time it was considered advisable to limit the distance to 3,000 ft. and to instal two units operating in relays.

After investigation of a Fluxo pump which had been in operation for more than a year at a cement plant nearby, and after considering the power requirements for compressed air, and the cost of upkeep, reliability of continuous operation on a 20 to 24 hour daily schedule, the Fluxo pump (Fig. 3), which is manufactured by F. L. Smidth & Co., was selected. The contract was awarded only under rigid guarantees of air consumption and capacity. The order was placed in April 1933 and the pumps reached Boulder City two months later within the guaranteed time limit.

The installation consists of two pump units placed 2,600 ft. apart, each provided with a surge bin above the pump and operating in relays. The first unit (pump No. 1) is situated near the " Himix " plant and the second unit (pump No. 2) is situated about 2,600 ft. therefrom and 530 ft. lower where the line reaches the canyon floor level. Pump No. 2 delivers the cement through

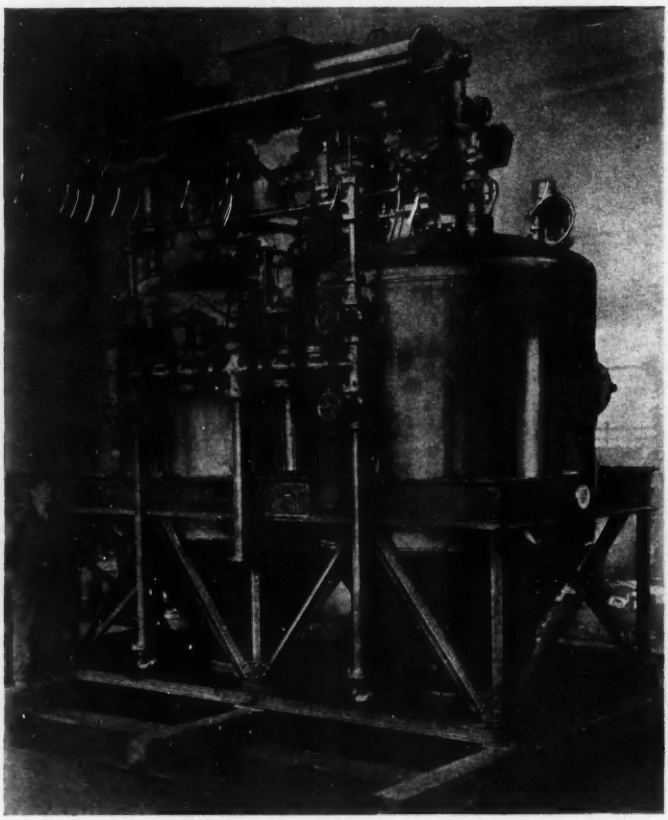


Fig. 3.

a 3,000-ft. horizontal line with a 100-ft. vertical rise at the end to storage bins at the " Lomix " plant. The two pump units are electrically interlocked so that pump No. 1 stops automatically if the surge bin over pump No. 2 has reached a predetermined level. A control switch at the " Lomix " plant enables the operator to stop pump No. 2 at any time; this in turn automatically stops

pump No. 1, but not until the line between the two pumps has been cleared of cement. The Fluxo pump does not require any adjustment or attention by the operator if the rate of delivery is changed. If the feed to the pump is reduced below the rated capacity, or if the flow of cement to the pump is

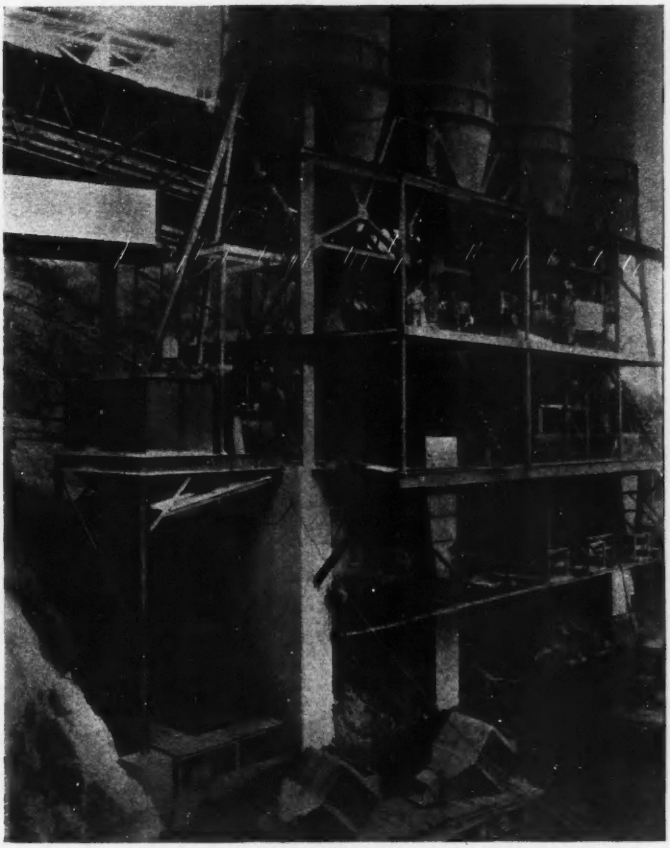


Fig. 4.

temporarily stopped, the pump stops automatically until the pump tanks have again been filled to the required level, when operation is automatically resumed. Fig. 4 shows the " Himix " concrete mixing plant ; the pump seen in the bottom left-hand corner pumps cement to a height of 130 ft. to silos above the concrete mixers.

Each pump unit consists of two pump tanks mounted side by side on a structural support (Fig. 3). While the cement is led by gravity through the

inlet valve into one tank, the cement in the other tank is being emptied under air pressure into the cement transport line. Then the cycle of operations is reversed, the tank inlet valve of the empty tank opens to receive a new charge of cement. The repetition of these cycles is entirely automatic, and a steady and rapid flow of cement emerges from the end of the pipeline.

There are no screw conveyors to force the material from the pump. The electro-pneumatic control system is operated from the lighting circuit with a small amount of power. Each pump unit is supplied with compressed air from the permanent compressor plant for moving the cement through the line, and came within the guaranteed air consumption. The only other motive power required is for agitating the cement before it enters the pump and for the high and low level devices on the machine, a total of 1½ h.p. per pump unit.

The guaranteed capacity of the two pumps when pumping cement over the distance of 5,600 ft. to the "Lomix" plant is 450 barrels per hour, but performance has often exceeded 550 barrels per hour. The quantity of cement pumped by pump No. 1 to the adjacent high-level plant through the 200-ft. pipeline, including a vertical rise of 130 ft., has reached 1,350 barrels per hour. The successful operation of these pumps through the 2,600-ft. and 3,000-ft. lines suggested the possibility of by-passing unit No. 2, and pumping the entire distance of 5,600 ft. by pump No. 1 only. This was tried during the early part of January 1934 and proved successful. Since that time the pumping has been accomplished with the single pump unit.

It appears from tests on pump No. 1, operating over a distance of 5,600 ft. in a single stage, that 450 barrels of cement per hour can be transported with about 10 per cent. less air than with the two pumps operating in relays.

No difficulty has been experienced from choking of the pipeline. At the time of writing over 2 million barrels of cement have been handled with no pipe replacement except on the last bend in the line, and the contractors state that repairs and maintenance of the pump are surprisingly low. The pump cycles are so uniform in respect of pressure and duration, as compared with the charge of cement handled per tank, that cycle diagrams from an automatic recorder have been used as a check on the amount of cement handled.

The Lime-Hydrate Process of Manufacture. By HERR HESS (*Zement*, No. 31, 1934).—Several advantages are obtained by substituting $Ca(OH)_2$ for $CaCO_3$ in the raw material for Portland cement, but the process is limited to places where lime is available as a waste product. A much larger surface is obtained with better conditions for sintering, there is no CO_2 to drive off, there is saving in grinding raw material, and so on. A serious disadvantage is that a large amount of water must be used in the slurry. Compared with the ordinary wet process more fuel is required for burning. Comparative figures are: wet process coal consumption 30.23 per cent. without filtration, 20.084 per cent. with filtration; lime-hydrate process, 39.6 per cent. without filtration, 30.57 per cent. with filtration. There is no difficulty in controlling the composition of the slurry, though lime is lost during filtration. Setting of the slurry is very slow and is not a source of trouble (this does not apply when hydraulic lime is used).

Hydration and Hardening of Calcium Aluminates and Silicates.

W. WATSON, B.Sc., and Q. L. CRADDOCK, M.Sc.

Calcium Aluminates.

THERE are four aluminates of calcium which may possibly exist in Portland cement. These are, in increasing proportion of lime, $3CaO.5Al_2O_3$, $CaO.Al_2O_3$, $5CaO.3Al_2O_3$, and $3CaO.Al_2O_3$. Although all of these may not be found in Portland cement it is instructive to examine their behaviour on hydration.

The majority of investigators ([2], [23], [24], [27]) have found that, with specimens of normal consistency, the setting time quickens as the percentage of CaO in the aluminate increases. Thus there is a gradual shortening of the setting time as we proceed from $3CaO.5Al_2O_3$.

Compound.	Setting Time.		H_2O used.
	Initial.	Final.	
			Per cent.
$3CaO.5Al_2O_3$	7 hrs.	8 to 24 hrs.	22
$CaO.Al_2O_3$	30 mins.	2 h. 10 m.	22
$5CaO.3Al_2O_3$	7 mins.	20 m.	30
$3CaO.Al_2O_3$	Flash setting.		50

The influence of gypsum on the setting time varies with the aluminate under examination. Both $3CaO.5Al_2O_3$ and $CaO.Al_2O_3$ are quickened, especially the former, the initial set being reduced to 0.5 hour and the final to 3 hours on the addition of 3 per cent. gypsum. The setting time of $5CaO.3Al_2O_3$, on the other hand, is lengthened by the addition of 3 per cent. gypsum, while $3CaO.Al_2O_3$ reacts too rapidly for the addition of gypsum to make any marked difference in its setting properties. Hydration begins rapidly in all cases, and with excess of water the reaction progresses quickly, and in a few days the aluminates are completely hydrated. With restricted amounts of water, however, the individual aluminate grains become coated with amorphous hydrated material through which further action proceeds with more or less difficulty. In the case of $3CaO.Al_2O_3$ immediate hydration occurs with all amounts of water up to 72 per cent. accompanied by sufficient evolution of heat to make the mix boil, even with the addition of 10 per cent. gypsum. The mass quickly agglomerates into balls hydrated on the surface, which prevent the access of water to the interior; consequently large masses of unhydrated material are present. Test pieces made with $3CaO.Al_2O_3$ adhere if stored in a damp chamber, but the interior is quite soft and the pat completely disintegrates in water; it does not harden under water even if kept in air for various periods first. The addition of 3 per cent. gypsum effects no material improvement, but 10 per cent. gypsum added to the aluminate before gauging gives test pieces which have a strength similar to that of $2CaO.SiO_2$ at 24 hours, but do not gain in strength with ageing. The

compound $5CaO.3Al_2O_3$ has a strength similar to Portland cement at the same ages if mixed with 3 per cent. gypsum. Both $CaO.Al_2O_3$ and $3CaO.5Al_2O_3$ have strengths much in excess of those given by Portland cement at the same ages if made without gypsum and stored for a quarter of the time in water and the rest of the time in air. Gypsum somewhat lowers the strength of both aluminates at 24 hours and 7 days, as does storage in water for the whole period.

Nagai and Naito[1] stated that comparative strength tests show that $CaO.Al_2O_3$ has the highest initial strength, but that both $3CaO.5Al_2O_3$ and $5CaO.3Al_2O_3$ are rapid hardening and give high 24-hour strengths.

A considerable amount of work has been done upon the products of hydration of the aluminates. In order to simplify considerations it is advisable to subdivide the processes of hydration under the following headings: (1) Hydration in excess water; (2) hydration in limited amounts of water, i.e., in specimens of normal consistency; (3) hydration in lime-water.

Most investigators agree that all the aluminates hydrate eventually to $3CaO.Al_2O_3xH_2O$, any alumina in excess being precipitated in the hydrated colloidal condition. Klein and Phillips[2] made an extensive study of the reactions which occur during the hydration of the aluminates. The compound $3CaO.Al_2O_3$ was shaken with lead shot in a vessel containing boiling distilled water. The amorphous hydration product first obtained gradually passes into crystalline material, the process being completed in eight days. Examination of slides of these crystals showed them to be hexagonal needles. When dried at 100 deg. C. on a steam plate for two hours their composition corresponds with the formula $3CaO.Al_2O_3.5{\cdot}5H_2O$, but if dried in a vacuum desiccator for 48 hours over sulphuric acid they have the composition $3CaO.Al_2O_3.9H_2O$. The gradual appearance of crystals of hydrated aluminate seems to indicate that the amorphous aluminate goes into solution and when that is sufficiently concentrated it crystallises out. Phillips[3] tested this theory by dialysing a suspension in water through a collodion sack. A solution was obtained which reacted faintly for Al_2O_3 and CaO. Further work showed that the solution was saturated at a concentration of 0.6 gr. per litre. The major portion of the material therefore remains in suspension, the degree of dispersion of which suggests that it is a colloidal suspension. It passes rapidly through a filter, does not diffuse or dialyse, shows development of the Tyndall cone, and is positively charged. The colloidal aluminate is not coagulated by heat or by alcohol, but is coagulated by freezing. It has a large capacity for the adsorption of ions and undissociated salts and its properties in general resemble those of the sols formed from the metallic oxides Fe_2O_3, Al_2O_3 and Cr_2O_3.

The work of Klein and Phillips[2] provided no evidence of the hydrolysis of $3CaO.Al_2O_3$ when mixed with water, as no free hydrated alumina or calcium hydrate were observed. This is contrary to the observations of Stern[4], Wells[5] and Lerch and Bogue.[6] Wells stated that the rapid setting of $3CaO.Al_2O_3$ may be due to the formation of a hydrate directly or by the reaction of hydrated lime (liberated when the aluminate first comes into contact with the water)

upon a less basic hydrated aluminate produced in the very early stages of setting. According to Lerch and Bogue, $3CaO.Al_2O_3$ hydrolyses in aqueous solution and, provided sufficient water is used and the soluble products are removed from time to time, the aluminate will eventually hydrolyse to $Ca(OH)_2$ and hydrated alumina. If, however, the soluble products are not removed hydrolysis proceeds to the formation of a less basic aluminate. Wells suggested that this aluminate, probably hydrated monocalcium aluminate, goes into solution and then, as more hydrated lime is dissolved, $3CaO.Al_2O_3.xH_2O$ is precipitated out. In the case of the other aluminates it is generally agreed that hydrolysis occurs with the deposition of hydrated alumina and $3CaO.Al_2O_3.xH_2O$, both in the amorphous form. The hydrated aluminate passes eventually into hydrated plates and needles.

Wells[5] considered that the hydration of aluminates less basic than $3CaO.Al_2O_3$ occurs through the following stages. Portions of the CaO and Al_2O_3 dissolve in the early stages of the reaction with the formation of the calcium salt of monobasic aluminic acid. These solutions are metastable and soon decompose with precipitation of part of the lime and alumina, more alumina being precipitated than lime. The metastable solutions contain 0.35 to 0.50 gr. CaO and 0.15 to 0.30 gr. Al_2O_3 per litre depending upon the composition of the anhydrous aluminate from which they are formed as well as upon the time of contact. As equilibrium is approached hydrated alumina and hydrated $3CaO.Al_2O_3$ are precipitated and the solution contains $CaO.Al_2O_3$ and $Ca(OH)_2$. As the concentration of $Ca(OH)_2$ is increased, increasing precipitation of alumina occurs.

Turning now to the composition of the hydrated aluminate, which is one of the final products during the setting and hardening of the aluminates, it has been mentioned that Klein and Phillips found that $3CaO.Al_2O_3$ did not hydrolyse, but simply hydrated to $3CaO.Al_2O_3.xH_2O$ where x varies with the drying conditions. They also showed that the amount of water absorbed by the aluminates decreases as the lime content increases. Thus $3CaO.5Al_2O_3$ has the greatest absorbing power while $3CaO.Al_2O_3$ has the lowest. The large water absorption of $CaO.Al_2O_3$, $5CaO.3Al_2O_3$, and $3CaO.5Al_2O_3$ is accounted for by the colloidal nature of the hydrated alumina which is split off. Shelton[7] confirmed this when he found that the amount of gel formed increases with the alumina content of the compound. Klein and Phillips also found that the weakly basic aluminates $CaO.Al_2O_3$ and $3CaO.5Al_2O_3$ do not absorb water appreciably above 110 deg. C., whereas $3CaO.Al_2O_3$ absorbs water up to 160 deg. C.

The bulk of the work done on the hydration products of the aluminates points to a substance of the formula $3CaO.Al_2O_3.xH_2O$, but a comprehensive survey of the literature discloses that four kinds of hydrated aluminates, with varying proportions of lime and alumina, are mentioned. Allen and Rogers[25] and Lafuma[26] mentioned the occurrence of a hydrated aluminate of the formula $2CaO.Al_2O_3.7H_2O$. Lafuma also confirmed the work of Le Chatelier[8] and Read[9] as to the presence of hydrated tetracalcium aluminate during the hydration of cement with lime-water. Wells[5] found that a hydrated aluminate of the formula

$4CaO.Al_2O_3.12H_2O$ appeared to be formed in a solution of the calcium salt of monobasic aluminic acid after the precipitation of alumina was complete. Travers and Schnoutka[10] made an extensive study of the polycalcium aluminates, which they prepared by mixing an aqueous solution of potassium aluminate $K.AlO_2.3H_2O$ with an aqueous solution of calcium nitrate containing lime water. They found that after a few minutes pure crystals of $3CaO.Al_2O_3.21H_2O$ were obtained but only existed when the P_H of the solution lay between 11.55 and 11.62. At P_H 11.62 to 11.79 they obtained spherolithic crystals and at P_H 11.79 to 11.89 hexagonal crystals. These crystals, upon analysis, were found to contain 3 to 4 molecules CaO to 1 molecule Al_2O_3 and apparently consisted of a solid solution of $Ca(OH)_2$ in $3CaO.Al_2O_3.21H_2O$. Above a P_H of 11.89 both hexagonal crystals of hydrated aluminate and rhombohedra of $Ca(OH)_2$ occurred together. Later[11] they investigated the products of reaction between lime-water and aqueous aluminium nitrate. It was found that the composition of the hydrated aluminate produced depended upon the concentrations employed and varied between $3CaO.Al_2O_3.12H_2O$ and $4CaO.Al_2O_3.12H_2O$. The formation of the hydrated product takes place in three stages, involving the precipitation of $Al(OH)_3$ followed by its solution in the lime-water as monocalcium aluminate and finally its precipitation again as polycalcium aluminate.

Klein and Phillips[2] investigated the action of excess lime-water upon $3CaO.Al_2O_3$. The crystalline material, when washed with alcohol and dried in a desiccator over sulphuric acid, corresponded to the composition $3CaO.Al_2O_3.10{\cdot}5H_2O$. This was confirmed by Lerch and Bogue in 1927.[6]

Koyanagi[12] concluded from his researches that one of the final products of the hydration of the aluminates corresponds to the formula $3CaO.Al_2O_3.xH_2O$ and criticised those who postulate a compound containing more lime than is demanded by this formula, considering that their analysis of the substance made no allowance for possible impurities in the form of $Ca(OH)_2$ and $CaCO_3$. He found that isolation and analysis of the pure compound were not simple matters since, however carefully the precipitation and filtration were carried out, it always appeared to become contaminated with carbonate and $Ca(OH)_2$ from the mother liquor which washing with absolute alcohol failed to remove. It was thus necessary to determine (*a*) SiO_2; (*b*) total CaO; (*c*) free CaO (by the glycerol method); (*d*) Al_2O_3; (*e*) CO_2; and (*f*) H_2O. In this way the CaO available for combination with Al_2O_3 can be determined.

Thorvaldson and Grace[13] found that $3CaO.Al_2O_3$ forms the hydrate $3CaO.Al_2O_3.6H_2O$ in water at room temperature and when heated at 150 deg. C. with steam in an autoclave. This compound forms isotropic crystals of refractive index = 1.604, and is slightly hygroscopic. This conforms very well with the composition of the hydrated aluminate obtained by Klein and Phillips but has different optical properties, the product obtained by the latter being double refracting. Thorvaldson and Grace found that the hexahydrate is stable at 100 deg. C. but at 275 to 300 deg. C. water is lost, yielding $3CaO.Al_2O_3.1{\cdot}5H_2O$. At still higher temperatures water is again slowly given up, the last of the com-

bined water being given up at 1,100 deg. C. At 750 deg. C. decomposition into CaO and $5CaO.3Al_2O_3$ occurs but recombination ensues after heating at 1,000 to 1,100 deg. C. or by heating in steam to 150 deg. C.

Table I, due to Koyanagi[12] shows the formulæ and optical characteristics of the hydrated calcium aluminates isolated by various authors.

TABLE I.

Formula.	Optical property.	Refractive indices.		Authors.
		W^D	E^D	
$3CaO.Al_2O_3.12H_2O$	Uniaxial negative	1.527	1.505	Thorvaldson.
$3CaO.Al_2O_3.10.5H_2O$	,, ,,	1.530	1.510	,,
$3CaO.Al_2O_3.8H_2O$	,, ,,	1.538	1.520	,,
$3CaO.Al_2O_3.10.5H_2O$	,, ,,	1.539	1.524	Koyanagi.
$3CaO.Al_2O_3.7H_2O$	,, ,,	1.538	1.523	Pulfrich & Link.
$4CaO.Al_2O_3.12H_2O$	,, ,,	1.52	1.505	L. S. Wells.

Klein and Phillips[2] found that the same reactions occur with moulded specimens as in the presence of excess water, but the transformation of the amorphous hydrate into the crystalline variety is much slower in the former case. Thus they concluded that tricalcium aluminate hydrates directly to $3CaO.Al_2O_3.xH_2O$ without any hydrolysis. The work of Colony[14] upon moulded specimens of $3CaO.Al_2O_3$ supplied evidence to the contrary. He found that plastic pieces could only be made by repeated kneading after cooling. These pieces disintegrated in a few hours if placed in water 24 hours after mixing, but if left for several days before immersion in water the disintegration was not so rapid; in a few months, however, they were badly cracked and expanded. The pieces which disintegrate slowly in water only retain some resemblance of their original form because their exteriors are thoroughly carbonated, the carbonated outer shells serving as a supporting framework for the otherwise thoroughly disintegrated mass. Moreover $Ca(OH)_2$ was formed and was converted into $CaCO_3$ by reaction with the CO_2 in the atmosphere, the outer surfaces of the test pieces being covered with calcite crystals, whereas the inner parts were soft, mushy, and gelatinous. Microscopic study of these disintegrated cylinders disclosed needles of crystalline hydrated $3CaO.Al_2O_3$ radiating from gelatinous grains and spherulites, a few minute crystalline plates of the same compound, and an amorphous gel. Therefore not only can simple hydration of $3CaO.Al_2O_3$ occur, but hydrolysis also takes place with the formation of $Ca(OH)_2$ and either a less basic hydrated aluminate or hydrated alumina. This supports Lerch and Bogue,[6] who concluded that both $5CaO.3Al_2O_3$ and $3CaO.Al_2O_3$ hydrolyse in the presence of water.

As previously stated, Klein and Phillips investigated the action of lime-water upon the calcium aluminates and showed that the same products are obtained as in plain water. They found no evidence of the formation of a hydrated tetracalcium aluminate as Le Chatelier had stated. They did find, however, that there appeared to be an action between the hydrated alumina

split off and the $Ca(OH)_2$ of the solution, yielding crystalline $3CaO.Al_2O_3.xH_2O$, particularly in the case of $CaO.Al_2O_3$.

Calcium Silicates.

Probably the only silicates which occur to any extent in good clinker are $3CaO.SiO_2$, β-$2CaO.SiO_2$, and some α-$2CaO.SiO_2$. Clinker produced either from coarse raw materials or by insufficient burning may also contain $CaO.SiO_2$ and γ-$2CaO.SiO_2$. Both these silicates are practically inert to hydration under all conditions. Calcium metasilicate ($CaO.SiO_2$) takes up an insignificant amount of water even when subjected to superheated steam in an autoclave at a pressure of 300 lb. per square inch. γ-$2CaO.SiO_2$, when heated in steam at atmospheric pressure for four hours at 110 deg. C., takes up only 0.5 per cent. water, and immersion in excess water or in an autoclave gives similar results. According to Newberry[15] and Rebuffat[16] γ-$2CaO.SiO_2$ does not hydrolyse or hydrate even when kept in contact with water for 29 days.

Klein and Phillips[2] showed that β-$2CaO.SiO_2$ is not hydrolysed at the end of 24 hours and a large proportion of it is not hydrolysed after three months. This confirms the earlier work of Le Chatelier[19] and Biel.[20] Lerch and Bogue[6] also found that test pieces of β-$2CaO.SiO_2$ stored under water contain a considerable amount of unhydrated material after four months. Moulded specimens of β-$2CaO.SiO_2$ have very little plasticity even when gypsum is present. No appreciable evolution of heat occurs on gauging, and the apparent set is only a drying out of the specimen, the 24-hour pats having no " ring," being granular in appearance with a marked lack of denseness. Tested without gypsum the strength is poor at 14 days even when the silicate is finely ground. After 28 days the strength gradually increases until at the end of three months it equals that of $3CaO.SiO_2$. Gypsum causes a slight increase in strength at all periods, but even so β-$2CaO.SiO_2$ sets too slowly and attains strength too slowly to be of any commercial value when used alone.

Thorvaldson and Vigfusson[21] found that $3CaO.SiO_2$ hydrolyses more rapidly than β-$2CaO.SiO_2$ and sets normally. When ground to 20 per cent. residue on a 200-mesh sieve the initial set takes place in two hours and the final in four hours. Addition of 3 per cent. gypsum reduces the initial set slightly but does not affect the final set. Briquettes made from $3CaO.SiO_2$ have good strength at the end of seven days ; the addition of gypsum increases the early strength somewhat but does not affect the later strength, the greater part of the strength still being attained in seven days. The broken test pieces are dense, vitreous, and glistening. No disintegration occurs after 28 days either in water or in the autoclave. $3CaO.SiO_2$ is slightly hydrated at the end of 24 hours, at the end of seven days the major portion is hydrated, and complete hydration occurs after four weeks with the production of a dense structure.

Lerch and Bogue[6] found that both β-$2CaO.SiO_2$ and $3CaO.SiO_2$ yield the same products when mixed with sufficient water to make them into cylinders. These products are (1) calcium hydroxide, and (2) amorphous hydrated calcium silicate whose composition approaches $CaO.SiO_2.xH_2O$.

According to Newberry[15] $3CaO.SiO_2$ hydrates to $3CaO.2SiO_2.3H_2O$ with the deposition of crystals of $Ca(OH)_2$. Later Newberry and Smith[17] found that, after shaking with water, one sample of $3CaO.SiO_2$ gave a varying residue of 1.5 to 2 equivalents of CaO to 1 equivalent of SiO_2. Ferrari[18] found that the reaction of $3CaO.SiO_2$ in mortars was

$$3CaO.SiO_2 + aq. = 2CaO.SiO_2.nH_2O + Ca(OH)_2$$

and that the hydrated silicate formed yields no more lime to the water. No evidence in support of Newberry's hydrate seems to be mentioned. Klein and Phillips,[2] however, stated that they were not able to observe the formation of any hydrated $CaO.SiO_2$ during the hydration of $3CaO.SiO_2$.

Lerch and Bogue[6] found that the extent of hydration is dependent upon the quantity of water used and on other factors influencing equilibrium. When the water present became saturated with $Ca(OH)_2$ the rate of hydrolysis was decreased. The gelatinous hydrated silicate formed coats the grains, acting as a protective envelope, and this also tends to retard hydrolysis. As $3CaO.SiO_2$ produces much more $Ca(OH)_2$ than does $2CaO.SiO_2$ and hydrolyses more rapidly, the greater strength of the former suggests that the strength of a Portland cement depends to a large extent upon the proportion of crystalline $Ca(OH)_2$ and hydrated calcium silicate present.

Draffin[22] found that when $3CaO.SiO_2$ is mixed with water, in the absence of air on a microscope slide, $Ca(OH)_2$ crystals appear after 12 hours and attain their maximum length after two to three weeks.

Bates and Klein[24] found that $3CaO.SiO_2$ was only slightly hydrated at the end of 24 hours. They made comparative tests of the amount of hydration of the silicates and mixtures of them with $3CaO.Al_2O_3$ and gypsum at the end of four weeks. Table II is a brief summary of their main results.

TABLE II.

Per cent. Components of Mixture.				Water taken up, per cent.
$3CaO.SiO_2$.	$2CaO.SiO_2$.	$3CaO.Al_2O_3$.	Gypsum.	
—	100	—	—	4.1 (13 weeks)
—	100	—	3	4.4 ,,
—	81	19	—	7.8 ,,
—	81	19	3	7.7 ,,
100	—	—	—	9.0 (4 weeks)
100	—	—	3	10.3 ,,
81	—	19	—	11.8 ,,
81	—	19	3	12.2 ,,
50	50	—	—	6.5 ,,
50	50	—	3	7.0 ,,
40.5	40.5	19	—	9.8 ,,
40.5	40.5	19	3	10.0 ,,

From the table it will be seen that the presence of $3CaO.Al_2O_3$ produces a very marked increase in the amount of hydration. This may not indicate that the silicates have hydrated to a greater extent but rather that the aluminate

has taken up the extra water, since it is well known that the aluminates, especially $3CaO.Al_2O_3$, hydrate very rapidly. Furthermore, the amount of water of hydration of the compounds at any period is not a measure of the strength developed, since $2CaO.SiO_2$ after one year with 5.5 per cent. H_2O of hydration has a strength almost as great as $3CaO.SiO_2$ with 11.5 per cent. H_2O, whereas tricalcium aluminate with 26.4 per cent. H_2O has a strength of only 100 lb. per square inch at the end of one year.

Bates and Klein[24] also made physical tests on mixtures of $3CaO.Al_2O_3$ with both β-$2CaO.SiO_2$ and $3CaO.SiO_2$. A mixture of 81 per cent. β-$2CaO.SiO_2$ and 19 per cent. $3CaO.Al_2O_3$ was flash-setting without gypsum, but with 3 per cent. gypsum the initial set took place ten minutes after gauging and the final set thirty minutes later. There was a marked increase in plasticity as compared with $2CaO.SiO_2$ alone, and a slight increase in strength. Examination of the briquettes after one month showed (*a*) minute crystals of calcium sulpho-aluminate scattered through the amorphous mass, and (*b*) the aluminate was practically completely hydrated, both amorphous and crystalline varieties being present.

A mixture of 81 per cent. $3CaO.SiO_2$ and 19 per cent. $3CaO.Al_2O_3$ had an initial set of seven minutes and a final set of two hours when ground without gypsum, and with 3 per cent. gypsum the initial set was lengthened to forty minutes but the final set was unaltered. This mixture gave very good strengths, being much better than those of any other compound or mixture tried. By replacing half the $3CaO.SiO_2$ by β-$2CaO.SiO_2$ the resulting mixture had similar setting properties, but the strengths were not so good, being nearly equal to those of $3CaO.SiO_2$ alone. They also tried a mixture of 50 per cent. $3CaO.SiO_2$ and 50 per cent. $2CaO.SiO_2$; both alone and with 3 per cent. gypsum the final set was slow, being six hours in both cases, but addition of gypsum quickened the initial set from three hours to one hour. The addition of $2CaO.SiO_2$ decreases the early strength compared with $3CaO.SiO_2$ alone, but the 28-day figures are as good and often better than $3CaO.SiO_2$ alone. All the mixtures made by Bates and Klein were ground in a batch mill to approximately 18 per cent. residue on the 200-mesh sieve.

From this survey it might be argued that the early strength of Portland cement, i.e., the strength at 24 hours, is due almost entirely to the aluminate present and that the subsequent increase in strength is due to the silicates, the influence of $2CaO.SiO_2$ being effective at a later date than the $3CaO.SiO_2$. This conception, however, leaves out of account two important factors, viz., the possibility of the presence of solid solutions or silico-aluminates, and the fineness of the cement. Petrographic examination of clinkers affords some indication of the existence of solid solutions, and their presence might exert a profound influence upon the early strength. As regards the fineness of cement it should be remembered that cement clinker is not a homogeneous substance, but consists of various compounds of differing degrees of hardness. Analysis of the fine and coarse fractions from ground clinker indicates that the silica compounds are more

readily reduced to flour than the alumina and iron compounds. Thus the proportion of silicates to aluminates in the fines may be higher than in the total cement, so that a chemical analysis of the whole cement may give a false idea of the effective cementing compounds for the production of early strength.

REFERENCES.

(1) Nagai and Naito, *J.S.C.I. Japan*, 33 (1930), 133B.
(2) Klein and Phillips, *Bur. Stds. Tech. Paper*, No. 43.
(3) Phillips, *J. Amer. Cer. Soc.*, 2 (1919), 708.
(4) Stern, *Chem. Zeitg.*, 32 (1908), 1029.
(5) Wells, *U.S. Bur. Stds. Research Paper*, No. 34 (1928).
(6) Lerch and Bogue, *J. Phys. Chem.*, 31 (1927), 1627.
(7) Shelton, *J. Ind. & Eng. Chem.*, 17 (1925), 1267.
(8) Le Chatelier, *J.S.C.I.*, 3 (1884), 485.
(9) Read, *J.S.C.I.*, 29 (1910), 735.
(10) Travers and Schnoutka, *Comptes Rendus*, 187 (1928), 381; *Comptes Rendus*, 188 (1929), 1677.
(11) Travers and Schnoutka, *Ann. Chem.* (1930), 255.
(12) Koyanagi, *Zement*, 45 (1931).
(13) Thorvaldson and Grace, *Can. J. Research*, 1 (1929), 36.
(14) Colony, *Concrete*, Mill Section, 40 (1932), 51.
(15) Newberry, *Cement & Eng. News*, Nov., 1902.
(16) Rebuffat, *Tonind. Ztg.*, 26 (1902), 1579.
(17) Newberry and Smith, *J.S.C.I.*, 22 (1903), 94.
(18) Ferrari, *Ciment*, 17 (1912), 81.
(19) Le Chatelier, *Ann. Mines*, 170 (1887), 388.
(20) Biel, *Proc. Inter. Assoc. Test. Mats.*, 2 (9) (1911) 51.
(21) Thorvaldson and Vigfusson, *Trans. Roy. Soc. Canada*, 3 (22), 423.
(22) Draffin, *J. Ind. & Eng. Chem.*, 20 (1928), 311.
(23) Bates, *J. Amer. Cer. Soc.*, 1 (1918), 679.
(24) Bates and Klein, *Bur. Stds. Tech. Paper*, No. 78 (1917); *J. Franklin Inst.*, 182, 398 (1916).
(25) Allen and Rogers, *see* Koyanagi (12).
(26) Lafuma, *see* Koyanagi (12).
(27) Bates, *Tech. Paper Bur. Stds.*, No. 197.

Strength in Relation to the Type of Hydration in Hardening Cement. By F. KRAUSS and C. PRUSSING (*Zement*, Nos. 34 and 35, 1934).—Most of the water, apart from that present in $Ca(OH)_2$ and hydrated silicates and aluminates, is combined zeolitically. Water combined zeolitically and in hydrated silicates and aluminates is not a factor in the strength attained by a cement after hardening; it can be removed from the hardened cement without reducing the strength. It is otherwise with water in $Ca(OH)_2$, the removal of which causes a drop in strength. When it is said that the withdrawal of water from the hydrated silicates and aluminates is without effect on the hardened cement it is not meant that the resulting silica and alumina compounds are of no importance for strength. Only the water content and the way the water is combined in the aluminates and silicates are unimportant for the strength of Portland cement.

CONVERSION DES MESURES ANGLAISES EN MESURES METRIQUES.

MESURES DE LONGUEUR.

1 inch (″) = 25,4 millimètres.
1 foot (′) = 304,8 millimètres.
1 yard (yd.) = 0,9144 mètre.

MESURES DE SUPERFICIE.

1 square inch (in.²) = 6,4516 centimètres carrés.
1 square foot (ft.²) = 929,03 centimètres carrés.
1 square yard (yd.²) = 0,83613 mètre carré.

MESURES DE VOLUME.

1 cubic inch (in.³) = 16,387 centimètres cubes.
1 cubic foot (ft.³) = 0,028317 mètre cube.
1 cubic yard (yd.³) = 0,76455 mètre cube.
1 cubic foot of ordinary Portland cement = 90 pounds = 40,82 kilogrammes.
1 cubic foot of rapid-hardening Portland cement = 80 pounds = 36,28 kilogrammes.
1 cubic foot fresh water = 62.4 pounds = 6.24 gallons = 28,32 litres.

MESURES DE CAPACITÉ.

1 English gallon (gall.) = 1.1016 U.S.A. gallons = 4,543 litres.
1 U.S.A. gallon (gall.) = 0.833 English gallons = 3,785 litres.
1 U.S.A. barrel of cement (bbl.) = 376 pounds = 170,52 kilogrammes.

POIDS.

1 ounce (oz.) = 28,3495 grammes.
1 pound (lb.) = 0,45359 kilogramme.
1 hundredweight (cwt.) = 50,802 kilogrammes.
1 ton (2240 pounds) = 1016,05 kilogrammes.

TENSIONS ET PRESSIONS.

1 pound per square inch (lb./in.²) = 0,070307 kilogrammes par centimètre carré = 0,069 hectopièze par centimètre carré = 0,068 atmosphere = 700 millimètres d'eau = 70 grammes par centimètre carré.
1 ton per square inch (ton/in.²) = 1,57488 kilogrammes par millimètre carré.
1 ton per square foot (ton/ft.²) = 1,0937 kilogrammes par centimètre carré.
1 inch of mercury at 32 degrees Fahrenheit = 0.4912 pound per square inch = 34,5 grammes par centimètre carré.
1 foot of water at 53 degrees Fahrenheit = 0.433 pound per square inch = 30,2 grammes per centimètre carré.

HYDRAULIQUES.

1 foot per second (ft./sec.) = 0,3048 mètre par second.
1 cubic foot per second (ft.³/sec.) = 1 cusec. = 539,200 English gallons per 24 hours = 647,100 United States gallons per 24 hours = 0,0283 mètre cube par second = 2,445,120 litres par 24 heures.
1 gallon per second (gall./sec.) = 4,546 litres par second.
1 English gallon per minute (gall./min.) = 0.00076 cubic feet per second = 4,543 litres par minute.

CHALEUR.

1 British Thermal Unit (B.T.U.) = 0,252 kilo calorie.
1 British Thermal Unit per foot run per minute (B.T.U./ft./min.) = 0,076 kilo calorie par mètre par minute.
1 British Thermal Unit per square foot (B.T.U./ft.²) = 2,71 kilo calories par mètre carré.
1 British Thermal Unit per square foot per hour per degree Fahrenheit (B.T.U./ft.²/hr./°F.) = 4,88 kilo calories par mètre carré par heure par degré Centigrade.
1 British Thermal Unit per cubic foot (B.T.U./ft.³) = 8,90 kilo calories par mètre cube.
1 British Thermal Unit per pound (B.T.U./lb.) = 0,555 kilo calorie par kilogramme.

TAMIS.

Sieve with 170 meshes per linear inch (mesh/in.²) = 4480 mailles par centimètre carré.
Sieve with 72 meshes per linear inch (mesh/in.) = 800 mailles par centimètre carré.

TEMPÉRATURE.

Degrees Fahrenheit (°F.) = $\frac{9}{5}$ degrés Centigrade + 32.

DIVERS.

1 pound per lineal foot (lb./ft. 1in.) = 1,362 grammes par mètre.
1 grain per gallon (gr./gall.) (British) = 14,3 grammes par mètre cube.
1 grain per gallon (gr./gall.) (U.S.A.) = 17,12 grammes par mètre cube.
1 grain per cubic foot (gr./ft.³) = 2,29 grammes par mètre cube.
1 foot-pound (ft.-lb.) = 0,138 kilogramme-mètre.
1 ounce per cubic foot (oz./ft.³) = 1 kilogramme par mètre cube.
1 horse power (h.p.) = 1,0139 cheval.
1 micron (μ) = 0.000039 inch = 0,001 millimètre.

CONVERSION FACTORS.

METRIC-ENGLISH.

LINEAR MEASURE.

1 millimètre (mm.) = 0.03937 inch.
1 mètre (m.) = 39.37 inches = 3.281 feet = 1.0936 yards.

SQUARE MEASURE.

1 centimètre carré (cm^2) = 0.155 square inch.
1 mètre carré (m^2) = 10.764 square feet = 1.196 square yards.

CUBIC MEASURE.

1 centimètre cube (cm^3) = 0.061 cubic inch.
1 mètre cube (m^3) = 35.315 cubic feet = 1.308 cubic yards.
1 mètre cube de ciment Portland = 3178.4 pounds (at 90 pounds per cubic foot).
1 mètre cube de ciment finement moulu = 2825.3 pounds (at 80 pounds per cubic foot).
1 mètre cube d'eau = 1000 litres = 35.315 cubic feet = 220.4 English gallons = 2,204 pounds.

MEASURE OF CAPACITY.

1 litre = 0.220 English gallon = 0.264 U.S.A. gallon = 61.023 cubic inches.
1 baril de ciment (bbl.) = 170,52 kilogrammes = 376 pounds (United States barrel).

WEIGHTS.

1 gramme (gr.) = 0.035 ounce.
1 kilogramme (kg.) = 2,204.6 pounds.
1 tonne (t.) = 1,000 kilogrammes = 0.984 ton.

STRESSES AND PRESSURES.

1 kilogramme par millimètre carré (kg/mm^2) = 0.635 ton per square inch.
1 kilogramme par centimètre carré (kg/cm^2) = 14.223 pounds per square inch.
1 hectopièze par centimètre carré (hpz/cm^2) = 14.5 pounds per square inch.
1 centimètre d'eau = 0.014 pounds per square inch.
1 mètre d'eau à 4 degrès Centigrade = 3.281 feet of water at 39.2 degrees Fahrenheit = 204 pounds per square foot.
1 millimètre de mercure = 0.039 inch of mercury at 32 degrees Fahrenheit.
1 atmosphere = 14.7 pounds per square inch.

HYDRAULICS.

1 mètre par seconde (m/s) = 3.218 feet per second.
1 mètre cube par seconde (m^3/s) = 35.315 cusecs = 13,227 English gallons per minute = 15,872 United States gallons per minute.
1 litre par seconde (l/s) = 0.22 gallons per second.

HEAT.

1 kilo calorie (kcal) = 3.97 British Thermal Units.
1 kilo calorie par kilogramme (kcal/kg) = 1.8 British Thermal Units per pound.
1 kilo calorie par mètre par minute (kcal/mn) = 1.211 British Thermal Units per foot run per minute.
1 kilo calorie per mètre carré ($kcal/m^2$) = 0.368 British Thermal Unit per square foot.
1 kilo calorie par mètre carré par heure par degrè Centigrade ($kcal/m^2$ h. °C.) = 2.05 British Thermal Units per square foot per hour per degree Fahrenheit.
1 kilo calorie par mètre cube ($kcal/m^3$) = 0.113 British Thermal Unit per cubic foot.

SIEVES.

Tamis de 4,900 mailles par centimètre carré ($4900/cm^2$) = 178 meshes per linear inch.
Tamis de 900 mailles par centimètre carré ($900/cm^2$) = 76 meshes per linear inch.
Tamis de 324 mailles par centimètre carré ($324/cm^2$) = 52 meshes per linear inch.

TEMPERATURE.

Degrés Centigrade (°C) = $\frac{5}{9}$ (degrees Fahrenheit − 32).

MISCELLANEOUS.

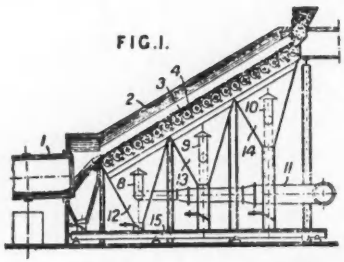
1 gramme par mètre (gr/m) = 0.00067 pounds per lineal foot.
1 gramme par mètre cube (g/m^3) = 0.07 grain per gallon (British) = 0.058 grain per gallon (U.S.A.) = 0.436 grain per cubic foot.
1 kilogramme-mètre (kg/m) = 7.233 foot-pounds.
1 kilogramme par mètre cube (kg/m^3) = 1 ounce per cubic foot.
1 force de cheval (ch) = 0.986 horse power.
1 micron (μ) = 0.001 millimètre = 0.000039 inch.

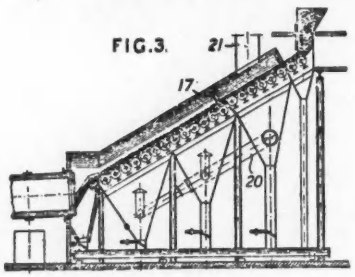
Recent Patents Relating to Cement.

Cement Manufacture.

No. 401,726. Borch, N. S., 28, Vendersgade, Copenhagen. May 18, 1932.

Raw cement material is passed, before entering a rotary kiln (1), through a preheater (2) traversed by the waste gases from the kiln and having a charge supporting and conveying bed comprising an inclined series of rotary rollers (3) between which are disposed stationary guides (4). The rollers are formed of a number of disks spaced apart on the driving shafts to provide spaces through which the gases pass downwardly to collecting pipes (8, 9, 10) leading to the outlet flue (11). The spaces between the disks are kept free by cleaning brushes or scrapers. The dust carried through the bed by the gases collects in chambers (12, 13, 14), and may be removed by a conveyor (15). Fig. 3 shows a modification in which the upper part of the roller bed is on a higher plane than the lower part and is enclosed by a partition (17); in this construction the gases which pass downwardly through the lower part of the bed are collected in a flue (20) from which they flow upwardly through the upper part of the bed and escape by the outlet (21).





CEMENT MANUFACTURE.

Portland Cements.

407,077.—Jorgensen, M. Vogel, 24, Bulowsvej, Frederiksberg, near Copenhagen. Sept. 10, 1932.

Cement raw material, either meal or slurry, is prepared for use as a gas-permeable layer by adjusting the water content and intensively mixing the material until it becomes homogeneous and of the consistency of moist earth, in which condition it is gas permeable when formed into layers and does not require further treatment such as modulising or briquetting. The water content is of the order of 10 to 20 per cent. of the mass. The mixing may be effected by stirring and grinding on an edge-runner, in a drum with grinding bodies, or in devices similar to those used in mixing concrete. Calcined or partially calcined cement meal may be added to the material.

Cement-Rubber Compositions.

402,811.—Swindin, N., Reno Works, Rosslyn Crescent, Wealdstone, Middlesex. June 7, 1932.

A quick-setting composition for the construction of roads, floors, and the like comprises a cement (e.g., Portland cement), an aqueous emulsion of rubber (e.g., latex) in an amount such that the dry rubber does not substantially exceed 10 per cent. of the whole mix, and a gelling agent for the rubber emulsion for accelerating the setting of the mix. The gelling agent may comprise "waste pickle" or a solution of ferrous chloride and hydrochloric acid, and iron powder may be added. In making a road, a number of layers of the composition may be applied, each succeeding layer containing a higher percentage of rubber than the preceding layer. For example, three layers may contain 3, 3½, and 5 per cent. of rubber respectively. The composition may contain the usual broken stone and sand aggregate. In an example, a mix comprises 52 lb. of ⅜-in. broken stone, 22 lb. of sand, 11 lb. of cement, 2 lb. of iron powder, 1 gallon of 40 per cent. latex and 160 grms. of casein dissolved in 1 quart of water and 240 c.c. of waste pickle.

Recent Patent Applications

389,872C.—PONTOPIDDAN: Manufacture of hydraulic cement.

400,813.—Riverside Cement Co.—Cement.

401,392.—H. S. Lee.—Cement manufacture.

401,522.—F. D. Snell.—Cements.

Waste-Gas Temperatures of Rotary Kilns.—IV.

By Dr.-Ing. Rudolf Frey.

APPENDIX.

Kiln running Data for the Calculation of the Exit Gas Temperature.

	Dry Process.	Guarantee test, September, 1931.	Test, December, 1930.	Guarantee test, November, 1931.
Kiln No.	I.	II.	III.	IV.
Diameter (metres)	2·8	2·8/3·3	3	3·3/3·6
Length (metres)	50	65	60	80
COAL :				
Gaseous constituents (per cent.)	20·26	20·20	22·30	17·93
Ash (per cent.)	19·7	16·30	9·96	17·30
Water (per cent.)	—	0·26	—	0·38
Temperature kiln head (deg. C.)	—	50·00	—	44·60
Calorific value (available) (kcal.)	6,821	6,009	7,127	6,620
Consumption (per cent.)	21·7	29·5	25·8	24·75
SLURRY OR RAW MATERIAL :				
Temperature (deg. C.)	30·0	35·00	30·0	27·70
Water content (per cent.)	7·0	36·50	9·5	36·60
Loss on ignition (per cent.)	33·90	36·51	35·24	36·36
CaO (per cent.)	43·20	43·42	44·10	43·11
MgO ,,	0·42	0·42	0·75	1·12
PRIMARY AIR :				
Temperature (deg. C.)	50	50	50	25·40
Weight per kg. clinker (kg.)	0·930	1·180	0·935	0·947
SECONDARY AIR :				
Temperature (deg. C.)	429	349	112	220
Weight per kg. clinker (kg.)	1·356	1·75	1·935	1·529
WASTE GAS :				
Temperature (deg. C.)	725	451	685	331
CO_2 (per cent.)	22·60	23·40	—	24·00
CO ,,	0·00	0·20	—	—
O_2 ,,	1·30	2·80	—	1·90
N_2 ,,	76·10	73·60	—	74·10
Excess of air	1·08	1·16	1·10	1·10
CLINKER :				
Output per twenty-four hours (tons)	197·5	210·6	199·7	292·0
Temperature—				
on entering cooler (deg. C.)	1,050	1,050	1,125	1,050
on leaving cooler (deg. C.)	80	80	320	297
Clinkering temperature (deg. C.)	1,420	1,420	1,525	1,400

Example of Heat Balance (Kiln No. II.)

BASE FIGURES

Slurry: Water content, 36·5 per cent.; 1 kg. clinker = 1·528 kg. raw material = 2·402 kg. slurry. Temperature of slurry at kiln inlet, 35 deg. C.

Coal: Temperature at kiln head 50 deg. C. Available calorific value of coal 6,009 kcal. per kg. Heat content at 50 deg. C. 10 kcal. per kg. (total: 6,019 kcal. per kg.). Consumption per 1 kg. clinker, 0·295 kg. per deg. C.

Waste gas: Temperature at kiln inlet 451 deg. C. Excess of air number 1·16. Weight of primary air, 1·180 kg. Weight of secondary air, 1·750 kg. Weight of dry waste gases, 3·77 kg. Heat content of steam at 451 deg. C., 807 kcal. Specific heat of waste gases at 451 deg. C., 0·250 kcal. per kg. per deg. C.

BALANCE FOR THE WHOLE PLANT

(I).—Quantities of heat introduced into the kiln—

		kcal.
With the slurry:		
$2{\cdot}402 \times 0{\cdot}487 \times 35$	=	41·0
$1{\cdot}180 \times 0{\cdot}241 \times 50$	=	14·2
With the secondary air: $1{\cdot}750 \times 0{\cdot}241 \times 20$	=	8·4
With the fuel: $0{\cdot}295 \times (6{,}009 + 10)$	=	1,775·6
Total	=	1,8392

(II).—Quantities of heat leaving the kiln:

		kcal.
Required for dissociation:		
For $CaCO_3$, $1{\cdot}184 \times 425$	=	503·9
For $MgCO_3$, $0{\cdot}013 \times 215$	=	2·9
		506·8
Freed during clinkering		100·0
		kcal.
Consumed for chemical transformation		406·8
Contained in dry waste gas: $3{\cdot}77 \times 0{\cdot}250 \times 451$	=	424·4
In the water content of the waste gases: $0{\cdot}874 \times 807$		705·3
In the clinker: $1 \times 0{\cdot}186 \times 180$	=	14·9
Total heat losses—as rest		277·8
Total		1,839·2

BALANCE FOR THE ROTARY TUBE ALONE

(I).—Quantities of heat introduced:

		kcal.
With the slurry		41·0
With the primary air		14·2
With the secondary air: $1{\cdot}750 \times 0{\cdot}242 \times 349$	=	148·0
With the fuel: $0{\cdot}295 \times 6{,}019$	=	1,775·6
Total		1,978·8

(II).—Quantities of heat carried off:

	kcal.
Consumed for chemical transformation	406·8
Contained in dry waste gas	424·4
In the water content of the waste gases	705·3
In the clinker of 1,050 deg. C.	262·0
Heat losses on the rotary tube	180·3
Total	1,978·8

BALANCE FOR THE COOLER ALONE

(I).—Quantities of heat introduced:	kcal.
With the clinker of 1,050 deg. C.	262.0
With the secondary air	8·4
Total	270·4

(II).—Quantities of heat carried off:	kcal.
In the secondary air	148·0
In the clinker	14·9
Heat losses on the cooler	107·3
Total	270·4

Compilation of Heat Balances

(for setting up the calculation of the temperature of the waste gas).

Kiln No...		1.	2.	3.	4.	5.	6.	7.	8.
Heat consumption	(kcal.)	1,480	1,776	1,842	1,641	2,010	1,910	1,995	1,870
Introduced									
in the raw mix	,,	10	10	10	10	10	10	10	10
in the water	,,	3	31	3	27	34	27	44	33
in the air	,,	12	22	15	14	17	16	16	14
Total	,,	1,505	1,839	1,870	1,692	2,071	1,963	2,065	1,927
Chemical requirement	,,	391	407	425	412	405	410	404	414
Clinker waste heat	,,	15	15	69	62	15	15	15	15
Carried off in the combustion gas	,,	479	367	551	238	436	447	332	344
Raw mix CO_2	,,	94	57	93	42	55	68	45	53
Steam	,,	107	705	147	667	900	755	1,140	816
Shell loss	,,	419	288	585	271	260	268	129	285
Total	,,	1,505	1,839	1,870	1,692	2,071	1,963	2,065	1,927
ROTARY TUBE:									
Introduced without pre-heating	,,	1,505	1,839	1,870	1,692	2,071	1,963	2,065	1,927
Pre-heating	,,	128	140	37	64	190	185	234	135
Total	,,	1,633	1,979	1,907	1,756	2,261	2,148	2,299	2,062
Carried off without clinker	,,	1,071	1,337	1,216	1,359	1,796	1,680	1,921	1,627
In the clinker	,,	262	262	280	259	262	262	262	262
Shell loss	,,	300	180	411	138	203	206	116	173
Total	,,	1,633	1,979	1,907	1,756	2,261	2,148	2,299	2,062
COOLER:									
Introduced in the clinker	,,	262	262	280	259	262	262	262	262
Shell loss	,,	119	108	174	133	57	62	13	112
Carried off in the clinker	,,	15	15	69	62	15	15	15	15
Pre-heating	,,	128	140	37	64	190	185	234	135
Carried off	,,	262	263	280	259	239	262	262	262

Examples for the Determination of the Heat Conductivity of the Rotary Kiln Wall

$$ti = \frac{T_s - T_g}{ln(T_s/T_g)} - 273 \; ; \; q_w = Q \, . \, G_h/F_a \; ; \; \lambda = 0.175 \, . \, \frac{q_w}{t_i - t_w}$$

Kiln No.	1.	2.	3.	4.	5.	6.	7.	8.
Clinkering temperature (deg. C.)	1,420	1,420	1,525	1,410	1,420	1,410	1,420	1,410
Waste heat ,, ,,	725	451	685	331	440	520	382	420
F_a (sq. metres)	440	545	565	842	227	570	393	450
Q (kcal. per kg.)	300	180	411	138	203	206	116	173
Output per hour G_h (kg. per hour)	8,240	8,780	8,330	12,150	2,800	8,960	7,486	6,250
q_w (kcal. per sq. m. per h.) ..	5,620	2,900	6,050	1,990	2,500	3,240	2,210	2,400
t_w (after Fig. 2) (deg. C.) ..	268	182	278	146	167	195	155	163
t_i (deg. C.)	1,037	866	1,059	780	857	897	817	840
$t_i - t_w$ (deg. C.)	769	684	771	634	690	702	662	677
λ (kcal. per sq. m. per h. per deg. C.)	1·280	0·668	1·370	0·550	0·635	0·809	0·558	0·621

Heat Conductivity Coefficients of Fireclay.

in 0·0001 gcal. per cm^2 . $h.°$. cm.

Temperature (deg. C.). ..	200	400	600	800	1,000	1,200
Chemiehütte	12	16	18	21	25	27
,, ...	14	18	22	24	40	—
Ullmann XI 262	14	18	22	24	26	27
,, ...	11	14	16	19	21	—
,, ...	9	11	12	13	—	—
,, ...	21	24	27	27	27	27
Hütte I	14	—	18	—	23	—
Catalogue of firm	—	—	—	17	45	—
,, ,, ...	—	—	—	—	34	—
,, ,, ...	—	—	—	—	40	—
Groeber	14	—	18	—	82	—
Average	13·57	16·68	19·2	20·7	31·2	43·5
Converted to kcal./m^2.h.°.m. gives	0·49	0·60	0·69	0·75	1·13	1·57

Examples for the Determination of the Heat Exchange Coefficient m.

$$m = \frac{Q \cdot G_h}{F_i \cdot \Theta_m}$$

Kiln No.	1.	2.	3.	4.	6.	8.
Inner surface F_i (sq. metres)	385	531	512	785	500	372
Output per hour G_h (kg.)	8,240	8,780	8,330	12,150	8,960	6,250
Chemical requirement (kcal.)	391	407	425	412	410	414
Heating raw mix ,,	292	296	299	298	298	298
Heating clinker ,,	118	118	144	114	114	116
Shell losses on tube ,,	300	180	411	138	206	173
Q ,,	1,101	1,001	1,279	962	1,028	1,001
Clinkering temperature (deg. C.)	1,410	1,420	1,525	1,400	1,450	1,410
Temp. of waste gas measured (deg. C.)	725	451	685	331	520	420
Calorific value of coal (kcal.)	6,821	6,019	7,127	6,620	6,500	7,000
Weight of flue gas per kg. coal (kg.)	11·52	11·00	12·12	11·40	11·70	12·00
Heat content raw material without pre-heating (kcal.)	592	547	588	580	555	583
Heat content air per kg. clinker (kcal.)	12	22	15	14	16	14
Pre-heating per kg. clinker (kcal.)	128	140	37	64	185	135
Pre-heating (kcal.)	140	162	52	78	201	149
Weight of flue gas per kg. clinker (kg.)	2·51	3·24	3·13	2·82	3.20	3·24
Pre-heating per kg. flue gas (kcal.)	56	50	17	28	63	46
Heat content raw material with pre-heating (kcal.)	648	597	605	608	618	629
t_{max} (deg. C.)	2,150	2,006	2,028	2,038	2,065	2,094
Temp. of raw material (deg. C.)	30	35	30	27·7	30	30
Mean temp. difference (deg. C.)	713	498	576	452	548	524
Mean heat exchange coefficient (kcal. per sq. m. h. deg. C.)	33·1	33·2	36·1	33·0	33·6	33·1

NOTE.—The clinkering temperatures of kilns Nos. 1 and 4 have been corrected according to Fig. 1.

Evolution of Carbonic Acid at Different Temperatures.

Temperature (deg. C.)	Per cent. $CaCO_3$ decomposed (average).
500	0·8
600	3·0
650	5·5
700	7·5
750	26·5
800	29·0
825	37·5
850	47·0
875	57·5
900	70·0
925	82·5
950	100·0

Comparison of Values computed and found in Running Kilns.

Kiln No.	1.	2.	3.	4.	7.
Diameter (metres)	2·8	2·8/3·3	3	3.3/3.6	2·5
Length ,,	50	65	60	85	50
Output per day in tons	197·5	210·6	199·7	292·0	180·8
Raw mix $CaCO_3$ (per cent.)	77·1	77·5	78·75	76·99	75·5
Water content (per cent.)	7·0	36·5	9·5	36·6	49·0
Avail. cal. value of coal (kcal.)	6,821	6,009	7,127	6,620	7,486
Computed waste gas temp. (deg. C.)	725	441	684	331	392
Measured waste gas temp. ,,	725	451	685	331	—
Computed heat requirement (kcal.)	1,514	1,741	1,860	1,580	1,999
Measured heat requirement ,,	1,480	1,775	1,842	1,640	1,995

Computation of the Feed of Coal Dust for a Rotary Kiln.

The volume of air necessary to inject the coal dust is in most cases not determined by the rules of combustion technics, but by the dynamical processes in the pipe line, in contradistinction to the necessary fineness of the coal which is determined by heating technics and not by the conditions for pneumatic conveying.

The minimum volume of air necessary for the introduction of the coal dust would be the volume of air required for the combustion, free of excess air, of the volatile constituents of the coal. With a composition of these constituents equal to that of an average gas of bituminous coal by incomplete combustion, the air requirement per kg. of gas is, according to Hütte (I, 4, VII), approximately 13·8 kg. Therefore, if the fuel contains f per cent. of volatile constituents

$$0{\cdot}138 \times f \text{ kg. air per kg. coal} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

This volume of air is, however, in most cases not sufficient because the dynamical resistances to be surmounted in the pipeline are too great, and for this reason an excessive pressure should prevail on the injecting fan.

The energy conveyed with the air in front of the coal dust nozzle must suffice to cover (1) kinetic energy of the fuel-air mixture at the burner, (2) frictional resistances in the pipeline from the nozzle to burning, (3) lifting energy for conveying the mixture over the height of the mixing nozzle (here it must be noted that the admissability of such a vertical conveying can be limited through technical reasons, such as deposition of coal dust, etc.).

To sum up, the following energy equation can be set up:

$$\frac{v^2_L \cdot G_L}{2g} = \frac{v^2_B \cdot (G_L + G_K)}{2g} + G_L + G_K) \cdot h + v^2_B \cdot \left(\frac{\lambda \cdot l}{d} + \zeta\right) \frac{G_L + G_K}{2g} \quad \ldots \quad (15)$$

Where G_L = the weight of the air in kg. per second
v_B the velocity of the air in the burner = 45 metres per second.
G_K the weight of the fuel in kg. per second.
g — 9·81 metres per second².
h the difference in height between nozzle and burner.
l the length of the pipeline in metres.
d the diameter of the pipeline and burner in metres.
λ the coefficient of friction of the pipeline.
ζ the coefficient of resistance for eventual elbows, etc.

According to which values are now assumed for the calculation, this equation will be used in various forms by reducing it after v_L after $v^2/2g = p/\gamma$, the pressure height of the fan, or by using it in the form of an equation between l and d.

Corresponding to the formulæ of hydrodynamics, further additional losses would have to be taken into consideration as items in the brackets of the last term. The size of the constant need not be discussed, as the velocity of burning is fixed by experience and the coefficient of friction is known from the theory of flow. For rough calculation there may serve $\lambda = 0{\cdot}03$, $\xi = 0{\cdot}15$ for a 1/8 elbow, $\gamma = 1{\cdot}24$ kg. per cubic metre.

If, as is often the case, the pressure p of the fan and the length l of the pipeline are given, the determination of the diameter is easy. Otherwise the calculation must be carried through for various values of d and l, and on the number of curves over the diameter as abscissa the most favourable operating point chosen for p. It is better to fix p and choose the operating point only from the dependence of d and l; thus, it is best to plot over the length of the pipeline the volume of primary air in per cent. of the total volume of air instead of d.

LITERATURE.

Ullmann.—" Enzyklopädie der chem. tech. Wissenschaften," Bd. XI. (Encyclopædia of chem. tech. sciences, Vol. XI).

Hütte.—" Taschenbuch f.d. praktischen Chemiker " (pocket-book for the practical chemist) ; " Des Ingenieurs Taschenbuch," Bd. 1 (engineers' pocket-book, Vol. 1).

Groeber.—" Grundgesetze der Wärmeleitung und des Wärmeüberganges " (Fundamental laws of heat conductivity and the passage of heat).

Wecke.—" Handbuch der Zementliterature," Berlin, 1927 (Manual of cement literature).

Timm.—" Wärmetechnische Grundlagen von Drehofen und Kohlenstaubfeuerungen, Zementverlag," 1906 (Heat technical fundamentals of rotary kilns and powdered coal furnaces).

Jochum.—" Der Drehofen als modernster Brennapparat, Braunschweig," 1911 (The rotary kiln as the most modern burning apparatus).

Nacken.—" Messungen der Temperaturen im Drehofen, Protokoll des Vereins Deutscher Portlandzementfabrikanten," 1921 (Measurements of the temperatures in the rotary kiln. Minutes of the Association of German Portland Cement Manufacturers, 1921).

Wecke.—Zement, 1930.

Bussmeyer.—" Heat Economy in the cement industry," *Cement and Cement Manufacture*, 1933.

Lellep.—" Wärmetechnische Untersuchung über den Wärmeaufwand beim Zementbrennen (Verbund-Rost-Drehofen)," Dissertation an der technischen Hochschule Braunschweig, 1930 (Heat technical examination on the heat consumption on burning cement. Compound-grate rotary kiln. Technical College, Braunschweig, 1930).

Laeger.—" Die gleichzeitige Verwendung von Schacht-und Drehofen zur Verbesserung der Wirtschaftlichkeit im Kalkwerk. Dissertation an der technischen Hochschule Berlin," 1932 (The simultaneous use of the shaft and rotary kiln for the improvement of the economy in lime works. Technical College, Berlin, 1932).

Hartner.—" Die spezifische Wärme des Zementklinkers," *Zement*, 1927 (The specific heat of cement clinker).

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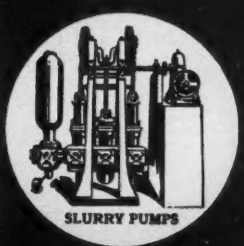
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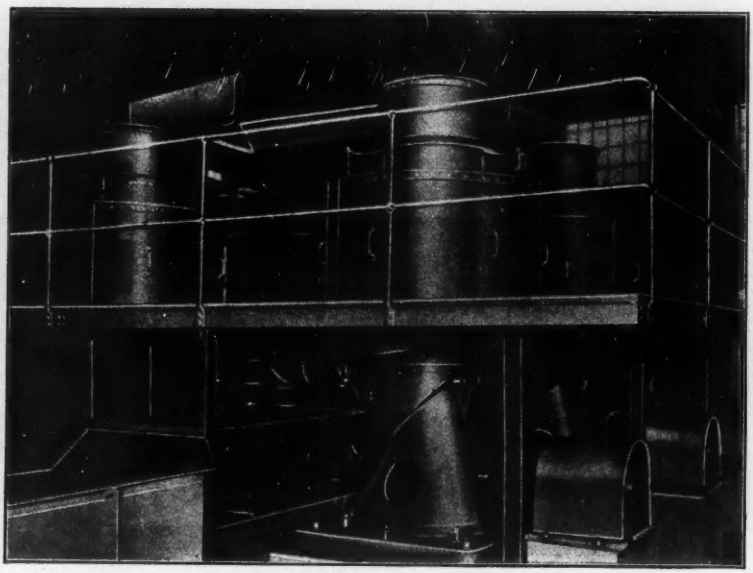

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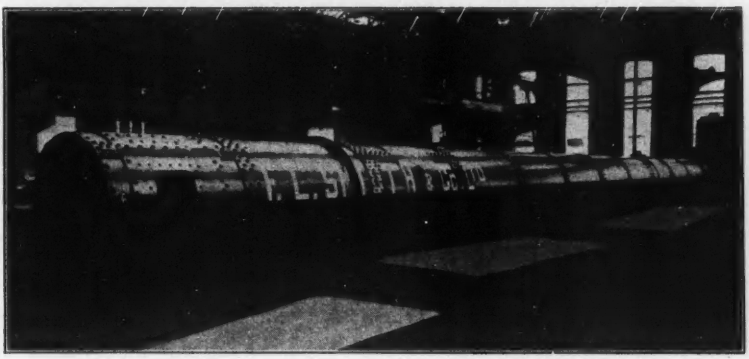

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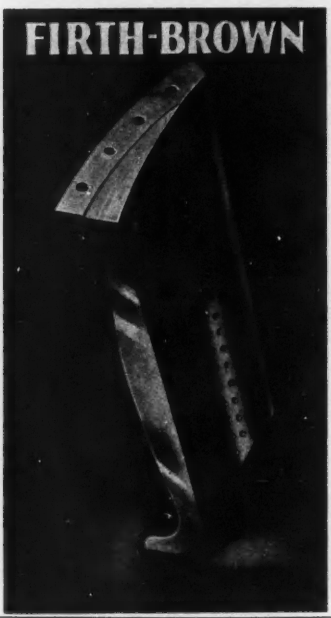

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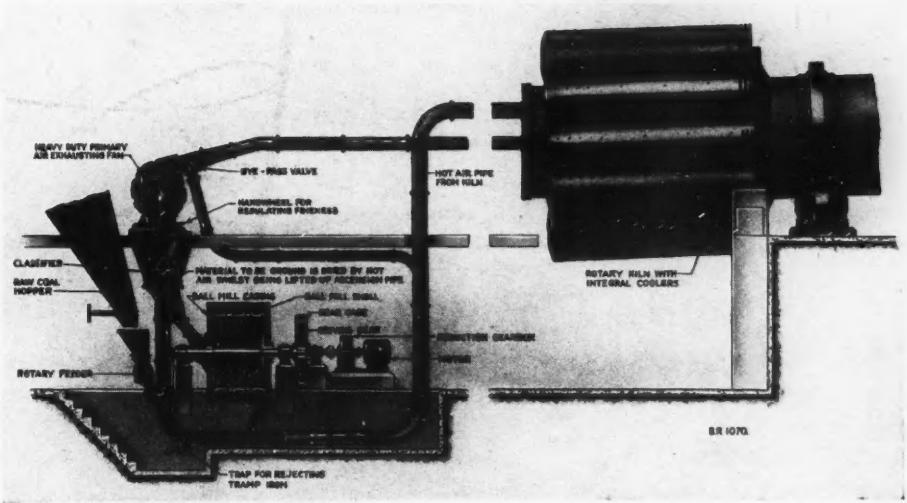

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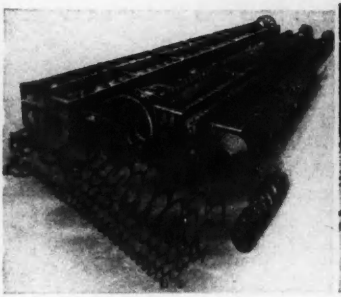

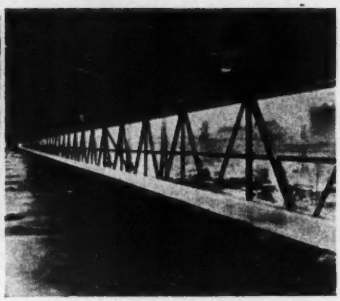

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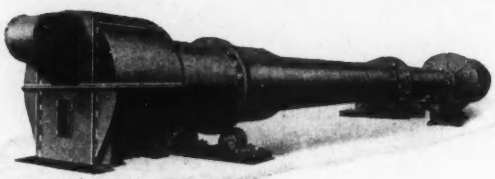

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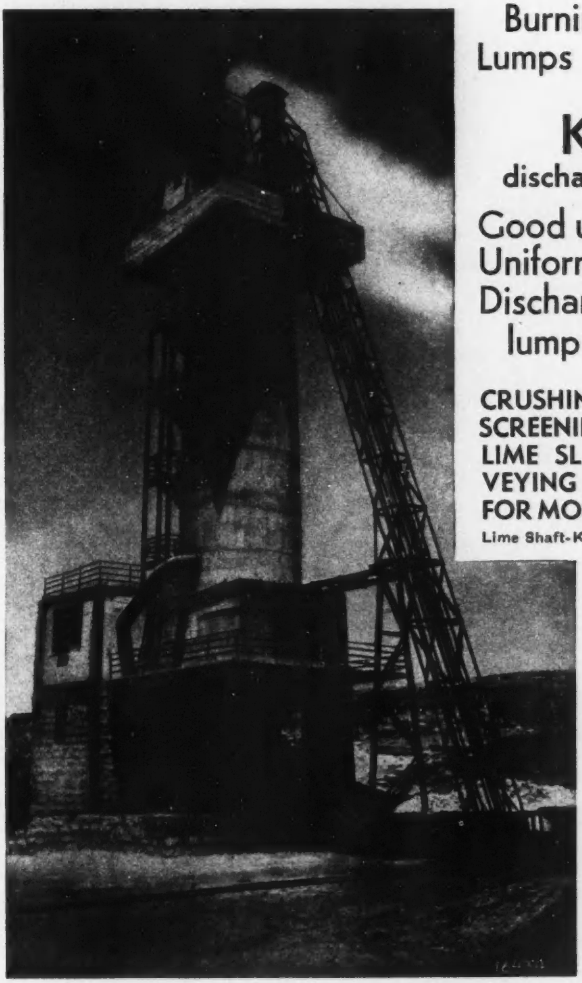

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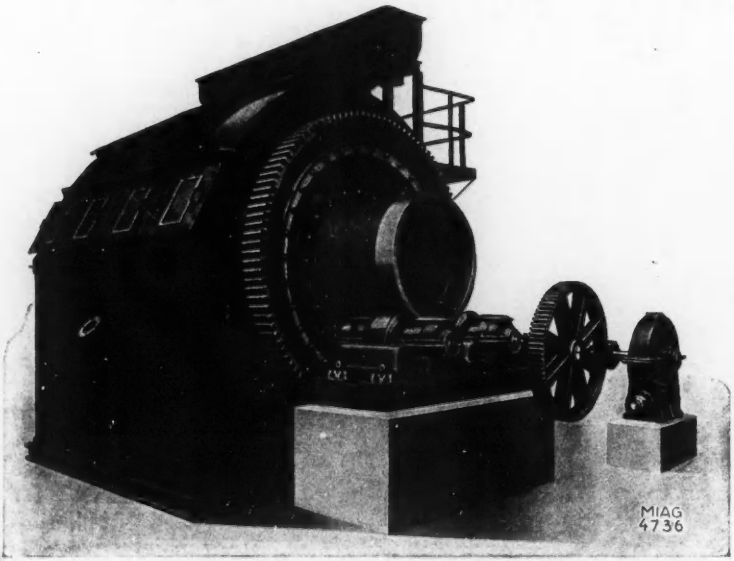

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FUEL CONSUMPTION realised with normal THICK SLURRY and in continuous working =

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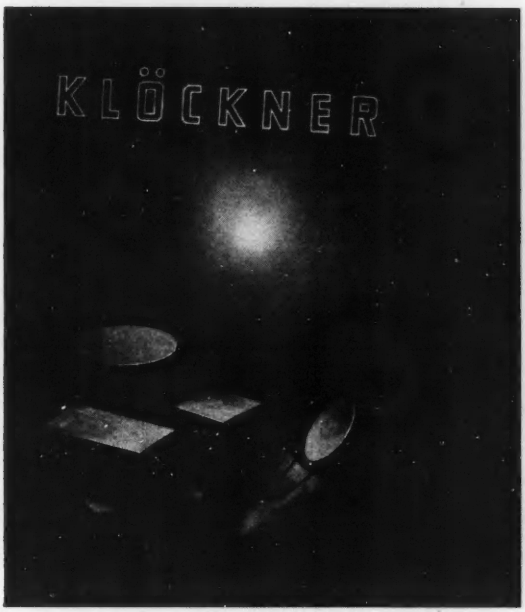

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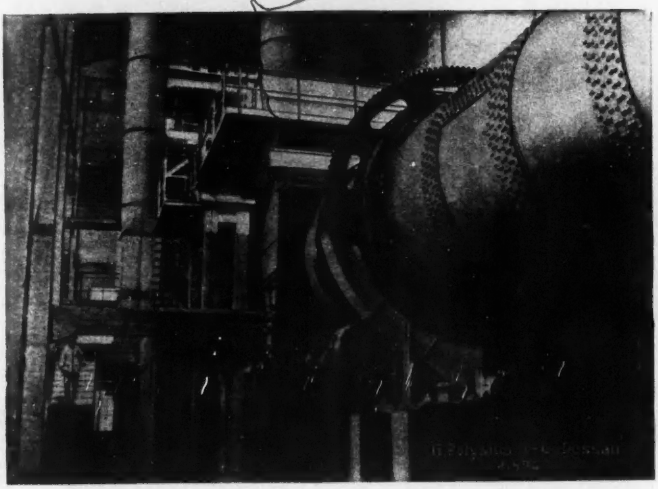

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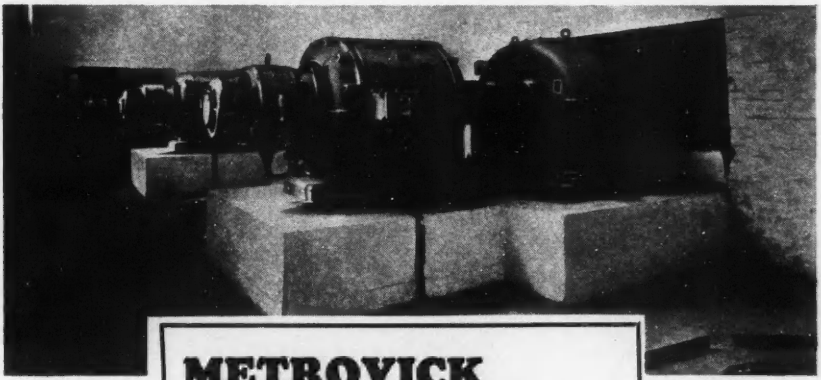

The above illustration shows the Mill Motor House at the Green Island Works with two Metrovick 475 H.P. Synchronous Induction Motors driving through Reduction Gears.

METROVICK EQUIPMENTS at GREEN ISLAND

CEMENT WORKS, HONG-KONG

108 Metrovick Motors and the necessary Control Gear, together with 6 Transformers and 13 Switchboards are installed at Green Island Cement Works, Hong-Kong.

AGGREGATE OUTPUT OF MOTORS 5,400 H.P.

108 MOTORS 6 TRANSFORMERS 13 SWITCHBOARDS

Below is illustrated a 60 H.P. "Metrovick" Motor driving Limestone Jaw Crusher. Part of a "Metrovick" 30 H.P. Motor is also seen on extreme right.

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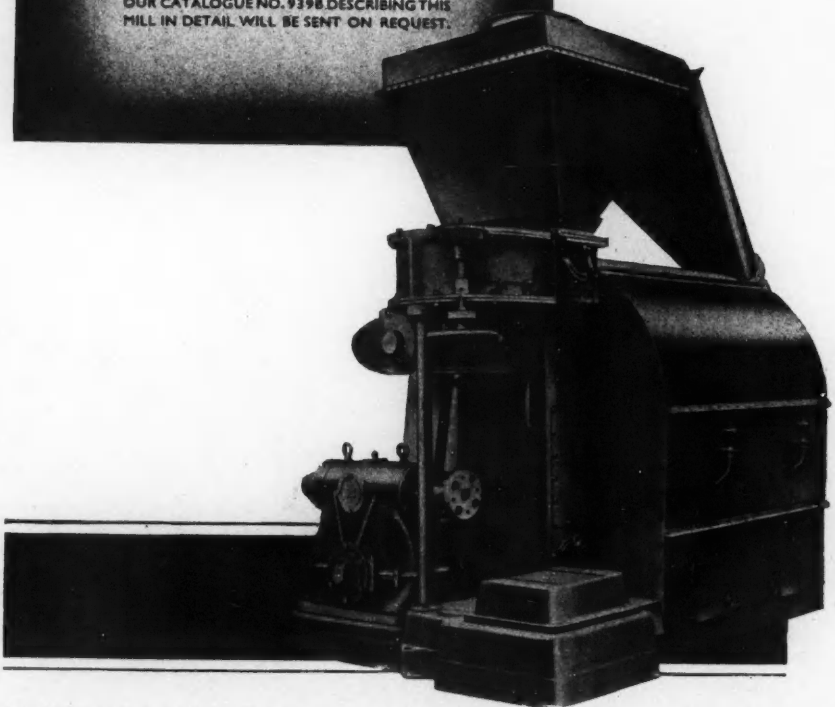

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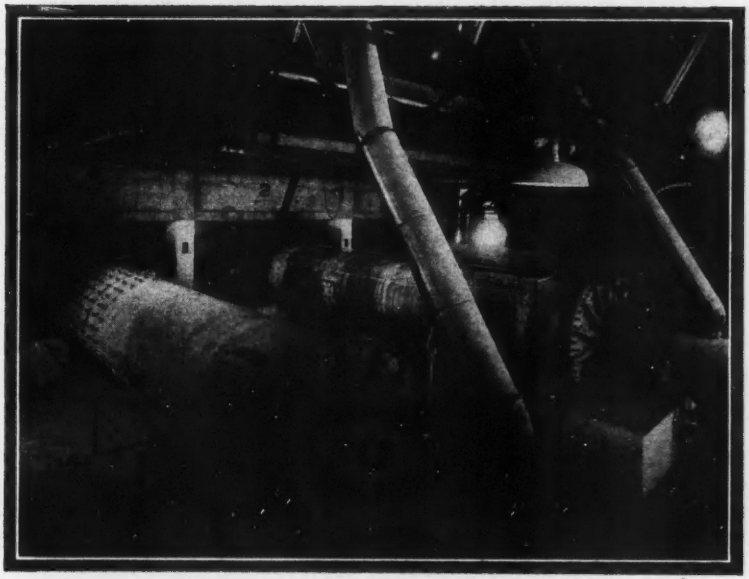

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The illustration shows three 6' 6" dia. × 36' 0" long Compound Tube Mills, part of a complete Cement Works in Hong Kong manufactured and erected by :

VICKERS-ARMSTRONGS LIMITED

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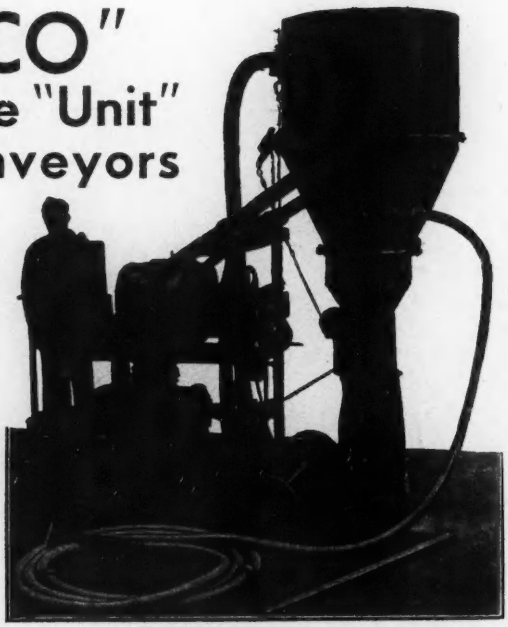
Head Office: VICKERS HOUSE, BROADWAY, LONDON, S.W.1.

"SIROCCO"
Transportable "Unit" Suction Conveyors



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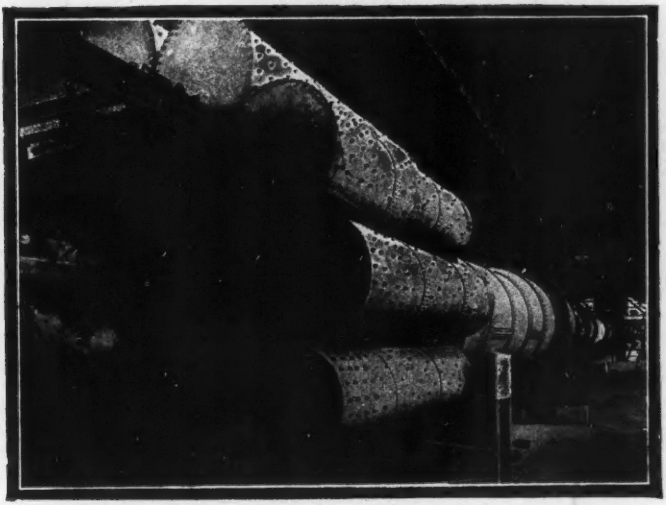

El grabado reproduce uno de tres grandes hornos rotatorios "REFLEX" provisto de Recuperador patentado, fabricado por los Sres. Vickers-Armstrongs, Ltd., de Barrow-in-Furness, Inglaterra. Este horno tiene una longitud total de 99.43 m., siendo el diámetro por encima de los cilindros del recuperador de 8.08 m.

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